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Digital Information Mobility Schema: A Data-Flow Model Featuring Risk-Resilient Approach Towards Effective Construction Worksite Synergy Utilizing Fuzzy-Analytic Hierarchy Process

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Abstract. The increasingly effective managing of risks in construction projects requires the stakeholders to collaborate, resulting in the need to integrate the use of Building Information Modelling (BIM) to mitigate the risks in project collaboration. Our understanding of strategic planning of BIM adoption amidst a pandemic is still limited, and it is widely accepted that COVID-19 is a long-term pandemic that require a constant and innovative range of mitigation approaches to protect public health. The significant construction advances emphasize remote work and digital tools that assist in the project's on-time completion. A fully digitalized approach is necessary for service continuity and rapid processing, particularly during a pandemic. Therefore, this study develops an adaptive digital collaboration framework based on Cloud-Based BIM technology to reduce risks while increasing workplace productivity and mobility. It resulted in a new way of managing the project information, enhancing the design team collaboration, and transforming 2D plans into 3D models. It integrates information to take a building through a virtual construction process long before it is completed, and each team member has access to the most up-to-date and current project information.

Keywords. Data Flow Model, Risk-Resilient Approach, Fuzzy-Analytic Hierarchy Process

1. Introduction

This study investigates project collaboration and data migration issues in the construction industry. The pandemic has hampered contractors worldwide [1]. It affected operations, productivity, expenditures, and profit in the construction business. Several ideas and frameworks are no longer useful, practicable, or enticing due to the economy [2]. Countries globally enforced global limitations, causing project delays, delayed production and distribution, material shortages, and stay-at-home orders.

Construction is becoming less effective and efficient [3]. Limited collaboration on and off the site has been one of the industry's major issues because most construction projects rely on strong productivity to deliver on schedule, and this depends on how well stakeholders can work together and communicate [4]. Most of the construction sector has focused on remote work and digital solutions to keep projects on time due to these problems [5]. Integrating a fully digitalized procedure is crucial for service continuity and quick processing. Some projects required remote design, pushing contractors to find new ways to be productive. Since then, engaging with essential partners has been more important than ever. The Architectural Engineering and Construction (AEC) sector uses BIM more (Building Information Modeling). Leading engineers and contractors use 4D and 5D simulation to re-plan and optimize projects. They can also use the internet to track staff well-being, buy building supplies, and manage scarce resources more accurately [6].

As we accept this generation of modern technologies and advances, the construction sector continues to mature. These modifications pave the path for longer-lasting strategies and risk-resilient methods. Therefore, this study proposes and develops the digital collaboration framework based on Cloud-Based BIM, which aims to mitigate the risks in project collaboration while increasing workplace productivity and mobility [7]. The project's scope, productivity, and ultimate cost can all be enhanced with a collaboration framework. It unearths fresh approaches to handle risks and issues in the building sector to improve project performance, focusing on the project's execution, dependability, and operations [8].

This study aims to create a collaborative working environment for the AEC sector by developing a framework model that could assist in resolving the collaboration risks in the existing construction industry. Since it is difficult to obtain corporate software, the scope of this research is limited to the current information supplied by the creators, previous research papers, and data mining. This study's findings could help building industry experts better comprehend the challenges of model cooperation and the easily available market solutions.

This study investigates the risks associated with project collaboration in the context of the current construction industry climate. In response, the purpose of this project is to create an adaptable digital collaboration framework utilizing Cloud-Based BIM Technology to reduce risks and improve workplace productivity and mobility. Several steps were undertaken to achieve the study's objectives, including the identification of collaboration-related risks and cloud-based BIM advantages, gathering of data, evaluation, and assessment, and framework development.

2. Related Studies

Multi-criteria decision analysis (MCDA) is a scientific process used by professionals to determine the best option, categorize alternatives, or rank alternatives. The MCDA approach was employed when decision-makers had to choose amongst many competing criteria. It includes arranging and solving choice issues using various criteria [9]. The MCDA methods were applied to various areas of civil engineering such as structural engineering [10], geotechnical engineering [11], water resources engineering [12], transportation engineering [13], environmental engineering [14], and construction engineering [15]. This study implemented the Fuzzy-AHP approach which is likewise implemented in different areas of construction engineering including cost overruns [16], supplier selection [17], construction and demolition waste management [18], project delivery method [19], and change order in construction [20]. The current study implemented the fuzzy-AHP approach in creating data-flow framework model featuring risk-resilient approach towards effective construction worksite synergy.

When the pairwise comparison matrix is highly consistent, the triangular Fuzzy AHP is more suited since it gives alternative criterion rankings for references to prevent the subjectivity of a small number of experts when their opinion on the criteria is highly consistent. The triangular fuzzy AHP is also relevant when a sufficient number of factors are of comparable relevance and the relative importance of various criteria is near to one another [21]. In addition, in fuzzy AHP, the experts develop pairwise comparisons for the criteria and alternatives based on each criterion, with the values of the integrated comparisons and the pairwise comparison values of the experts being converted into triangular fuzzy numbers. In addition, the best option was stated with regard to the combination of priority weights for criteria and alternatives [22]

3. Methodology

This section of the paper presents the breakdown of steps and processes substantial in accomplishing the study's significant objectives, which are as follows: (1) assess the present condition of the construction industry and identify the risks associated with project collaboration, (2) determine the technological capabilities of the Cloud-Based BIM, (3) develop the adaptive digital collaboration framework, (4) evaluate the adaptability, functionality, and reliability of the framework, and (5) formulate a conclusion and recommendations regarding the success of the study towards minimizing risks and improving workplace productivity. Specifically, this part presented an overview of the research design, setting, study respondents, data-gathering procedures, and instruments.

3.1. PHASE 1: Identification of Collaboration-Related Risks and Cloud-Based BIM Benefits

From the review, researchers identified all probable and underlying project risks. This technique proved the researchers' initial premise that a deteriorating construction industry creates project collaboration hazards. This step analyzed publications, journals, studies, forums, and statements from companies that have used Cloud-based BIM Technology to determine its features and capabilities. The researchers examined how Cloud-Based BIM Technology might lessen the RBS risks. This process helped produce framework factors and tactics. Researchers grouped hazards into subcategories and rate benefits by area of concern. This approach was used to arrange risks by concentration and characterize them by probability and project impact.

3.2. PHASE 2: Data Collection, Analysis, and Interpretation

After the initial phase, the survey questionnaire is constructed based on the early findings to perform a survey study. Researchers surveyed AEC workers in the Philippines to collect data. Instead, researchers set a deadline for survey responders. The survey was distributed via email, and other online platforms. The test findings were interpreted descriptively. The statistical treatment created the weights of variables for the Fuzzy Analytical Hierarchy Process, which validated the efficacy of the Adaptive Digital Collaboration Framework in minimizing risks and boosting workplace productivity and mobility. Researchers developed variable weights from past statistical tests. Fuzzy AHP output was used to finalize the study framework.

3.3. PHASE 3: Framework Development

To oversee the initial development of the Digital Collaboration Framework, the researchers aggregated all the consideration elements and tactics gleaned from the first phase procedures' output. A further evaluation of the risks and rewards was conducted to determine where mitigation measures should be placed and successfully construct the framework. This was the primary activity of the study; this is where the actual framework creation began. Before evaluating the initial structure of the Adaptive Digital Collaboration Framework, the researchers regularly examined the accumulated aspects and tactics to identify defects for revision and improve the framework's quality.

3.4. Statistical Treatment

The researcher's statistical treatment started from the first phase of the study during the correlation analysis of the present condition of the construction industry with the risks related to project collaboration. The researchers did the following statistical treatment once the researchers have collected all the data from the qualified respondents within the given timeline. To interpret and summarize the gathered data, the researchers initially performed descriptive statistical treatment such as mean, geometric mean, standard deviation, and test for skewness [23]. The researchers used these data interpretation methods to transform the factors assessed numerically. The researchers used a Fuzzy AHP to predict the framework's adaptability, reliability, and functionality success [24]. In performing the Fuzzy AHP, the researchers derived the weights of each variable from the output of the previous statistical tests [25]. The output for the Fuzzy AHP was the basis of the finalization of the framework and study.

4. Result and Discussions

4.1. Risks in Project Collaboration

Since the researchers opted to utilize a Likert scale to get feedback from respondents, the most probable and possible interpretation of the results would be to get its weighted mean. However, before moving on to the Fuzzy AHP, the researchers divided the risks into clusters to mainly categorize them, which can significantly help build the framework and provide a better division of items for pairwise comparison matrices. The clustered items are presented in Figure 2.

Table 1 shows the derived intervals based on the weighted mean difference used by the researchers to get the triangular fuzzy number of each risk item. Each fuzzy number represents the level of priority of each risk [26].

Table 1. Triangular Fuzzy Numbers Based on Weighted Mean Difference

Weighted Mean Difference	Fuzzy Number	Triangular Fuzzy Scale	Inverse Value	Linguistic Term
0.00	1	(1, 1, 1)	(1, 1, 1)	Equal Priority
0.01 – 0.1088	2	(1, 2, 3)	(1/3, 1/2, 1)	Equal to Weak Priority
0.1089 – 0.2077	3	(2, 3, 4)	(1/4, 1/3, 1/2)	Weak Priority
0.2078 – 0.3066	4	(3, 4, 5)	(1/5, 1/4, 1/3)	Weak to Strong Priority
0.3067 – 0.4055	5	(4, 5, 6)	(1/6, 1/5, 1/4)	Strong Priority
0.4056 – 0.5044	6	(5, 6, 7)	(1/7, 1/6, 1/5)	Strong to Very Strong Priority
0.5045 – 0.6033	7	(6, 7, 8)	(1/8, 1/7, 1/6)	Very Strong Priority
0.6034 – 0.7022	8	(7, 8, 9)	(1/9, 1/8, 1/7)	Very Strong to Extreme Priority
0.7023 – 0.80	9	(9, 9, 9)	(1/9, 1/9, 1/9)	Extreme Priority

The BIM benefits includes BIM allows multi-disciplinary information integration to produce more informed and effective design and construction risk reduction solutions (B1), Reduces risks associated with inefficient stakeholder communication during project management (B2), Inter-stakeholder collaboration may decrease design risk throughout the decision-making process (B3), Reduced risks during construction and implementation due to BIM's collision detection algorithm (B4), Allows risk mitigation to be handled more quickly by keeping track of the project and reducing project uncertainty (B5), Assists with risk assessment and mitigation throughout the project life cycle (B6), It helps the project participants share risk information, helping to raise everyone's understanding of potential risks (B7), Enables change management via regular revision control on a shared platform (B8), Reduces construction risks by providing geographical data on potential risk occurrences (B9), Can reduce the design errors and reworks (B10), Enhances and improves the overall quality of the project design (B11), Can be of assistance in design cooperation and work-sharing (B12), Increases the project team's productivity (B13), Reduces the need for re-gathering and re-formatting of data (B14), Simplifies file management and access to drawings for faster evaluation (B15), An effective communication platform during the time of the pandemic (B16), A reliable basis for decision-making in the entire project life cycle (B17), Facilitates collaboration through high-frequency data management for all the disciplines involved in the project (B18), Allows the project stakeholders to achieve a joint objective of the project (B19), Provides construction stakeholders more excellent visualization of project information (B20), Can capture and maintain the essential knowledge among relevant stakeholders, enabling them to examine the feasibility of reusing building components for projects (B21), Provides access to the most up-to-date project documents to all disciplines (B22), Aid in developing more sustainable infrastructure that meets the needs of its owners and occupants by assisting in the provision of necessary value judgments (B23), An aid to overcome challenges such as information loss, ownership, and legal disputes (B24), and Enhances cooperation between project team members (B25). The stacked bar chart representation of the benefits of using BIM is shown in Figure 3.

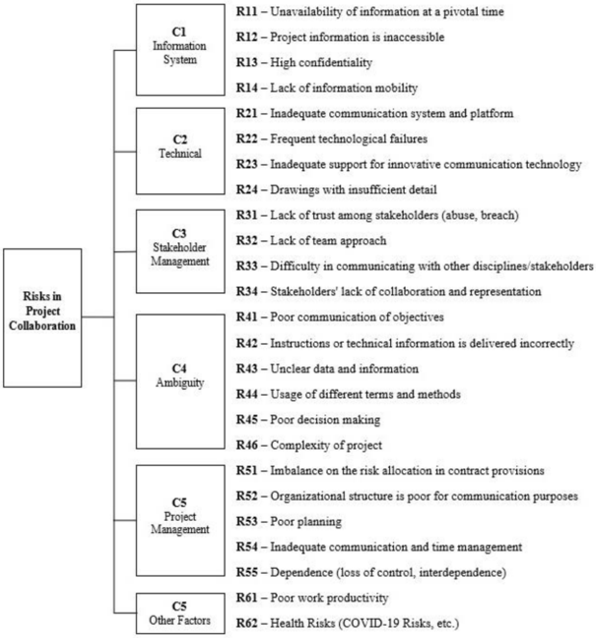

Figure 1. Clustered Risk Items

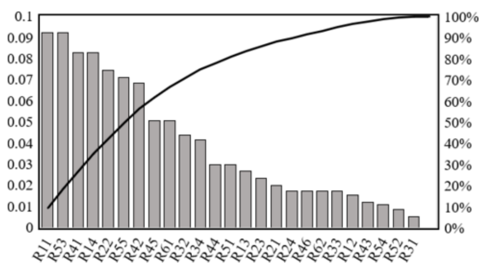

Figure 2. Clustered Risk Items

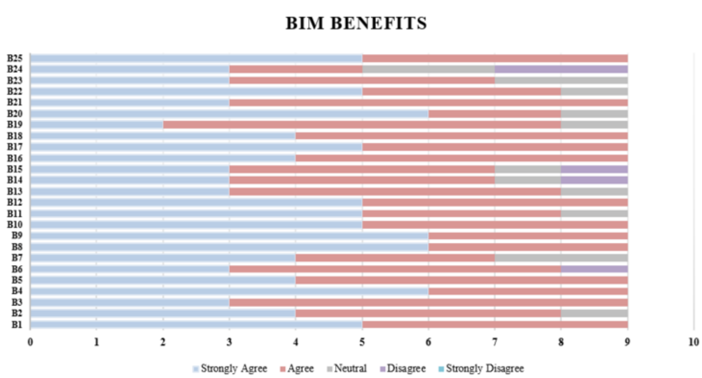

Figure 3. Stacked Bar Chart representation of the benefits of using BIM

BIM benefits have been quantified extensively (BIM). Despite widespread use, relationships between project risks and BIM advantages were studied. BIM provides multi-disciplinary information integration to produce better informed and effective design and construction risk reduction solutions, as indicated in the first category of project collaboration hazards [27]. Sharing risk information helps project participants identify potential risks. BIM-experienced respondents validated this notion. BIM is said to lessen risks during construction and implementation due to its collision detection algorithm [28].

All partners in a joint effort must be committed. Each stakeholder should know their role in the team and have clear responsibilities. Flexible organizations can benefit from the pooled connectivity and project effectiveness. Maintaining clear communication lines is a risk in project collaboration. These risks can be minimized with BIM because it: (I) provides construction stakeholders with better visualization of project information; (II) improves cooperation between project team members; (III) captures and maintains essential knowledge among relevant stakeholders, allowing them to examine the feasibility of reusing building components for projects. Ambiguities in construction projects typically result from the project's complexity, inaccurate instructions or technical information, imprecise data and information, and bad decision making. BIM is a design program whose documentation flows from planning to implementation. It helps overcome information loss, ownership, and legal conflicts, minimizes the need to re-gather and re-format data, and aids design cooperation and work sharing. BIM may mitigate project management risks including imbalanced risk distribution in contract conditions by providing up-to-date project documents to all disciplines [29]. Poor planning, communication, time management, and interdependence can be reduced by sharing risk information among project participants. High-frequency data management helps all project disciplines collaborate.

Furthermore, it allows risk mitigation to be handled more quickly by keeping track of the project and reducing project uncertainty. Lastly, it simplifies file management and access to drawings for faster evaluation. Other factors for the risks in construction include poor work productivity and health risks such as COVID-19. Since we are in a pandemic, BIM offers an effective communication platform during the pandemic, enhancing and improving the overall quality of the project design. This provides a secure collaboration environment where the design team, construction team, and client can access, view, and share building design modeling and document development.

4.2. Framework Development

The formulated framework is a systematized strategy that aims to achieve effective collaboration and information mobility in all aspects of the project and mitigate the significant risks related to project collaboration. The framework strives to make the collaboration between stakeholders simpler and faster, thus resulting in orderly workplace productivity.

The framework consists of four (4) main phases, including project planning, design and collaboration, construction, and operation to achieve seamless workplace collaboration and mobility. This framework could help the construction industry enter a new era where they could have the confidence to do every job coordinately and coherently despite the given situation (pandemic era). Three of the framework's phases were retrieved from the manual work or traditional construction methodology. At the same time, there is an additional step based on the BIM process associated with cloud technology.

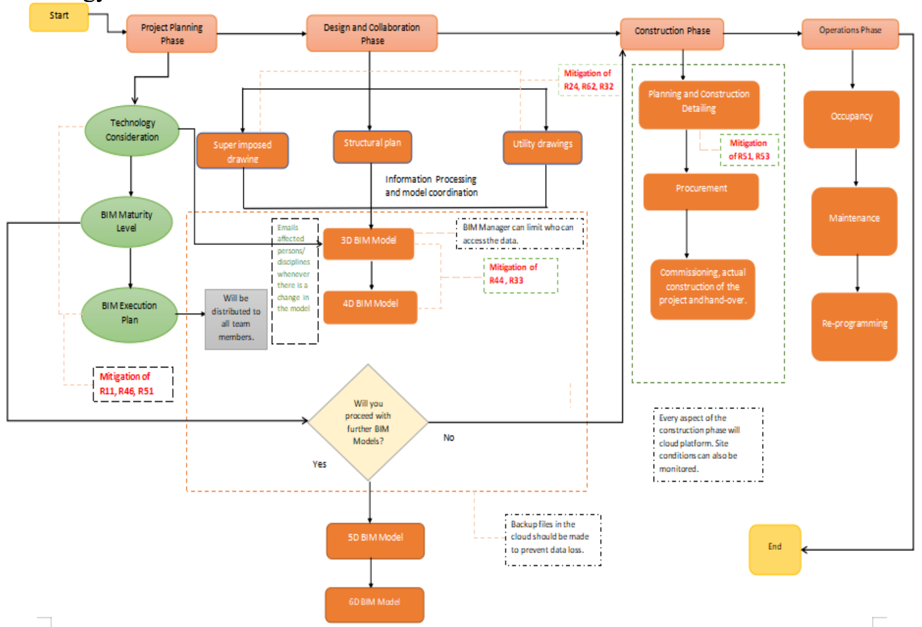

Figure 4. Developed Cloud-Based BIM Framework

5. Conclusion

The scarcity of collaboration and trust in the present-time construction industry caused friction and disagreements, affecting the project's design, quality, and output, compelling the industry to embrace more advanced technologies and enhance remote work activities to counter this situation.

This study discussed how the digital collaboration framework is significant to the construction industry by unveiling the common risks that the industry is facing in its present condition, as well as implementing enabling factors and proposing risk mitigation techniques that might help enhance workplace productivity, efficiency, and collaboration between project participants and improve project outcomes. This study also emphasized that collaboration challenges and obstacles brought by the pandemic, such as unprecedented delays, interruptions, and unpredictability in construction projects, can be overcome through digital solutions by enhancing integration, partnering, and contractual governance. Aside from risks, the study also validated the benefits of Cloud-Based BIM in the construction industry. The validation results have helped assess the framework's capability and effectiveness in mitigating the risks.

Different degrees of data security and network speeds risk data loss across organizations. Difficulties may occur in management due to variances in Cloud-Based BIM knowledge among the AEC sector that utilize various professional models. In addition, different BIM standards and specifications could result in the loss of information and hinder collaboration. These issues should be addressed immediately to prevent future disputes. Only the function of BIMs in minimizing risks in project cooperation was studied and interpreted. Future study is required to merge managerial and technical components, requiring relevant BIM software. Lastly, the integrated management of the ultimate risk reduction approach must be validated in a real-world project.

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